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Persistent Ocean Surveillance

Station Keeping Buoys

Program Overview

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- **Develop and demonstrate environmentally-powered station-keeping for Persistent Ocean Surveillance**
- **Products:**
 - **Demonstrated technologies to station-keep in 2 knot currents using local environmental effects**
 - **< 250 m watch radius for 4 weeks 90% of the time**
 - **< 2,500 m watch radius for 4 weeks 100% of the time**
 - **Tactical-sized buoy prototype (nominally 100 lbs, 5-8 inches cylindrical diameter) for ocean sensing and monitoring of critical areas**



State of the Art/Practice



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- Current small sensors are limited by drift and power
- Position kept by labor-intensive mooring
- Long-staying buoys are large
- Technologies now available:
 - Small electronics
 - Cheap, low power GPS
 - Energy harvesting

DARPA challenge:

- ***Efficient environment energy extraction/exploitation***
- ***Buoy propulsion modalities***
- ***Effective buoy design***

	Today	This program
Size	Standard sizes (A through E)	Same
Endurance	Hours	Weeks
Station-keeping	Drifting or moored (no SK); gliders	250 meters (90% of time) in Beaufort Scale 6 (22- 27 kt winds; 10 ft waves)
Surface signature	Exposed	Minimum exposure
Position estimate	None or GPS	GPS



Speed	2.4 knots
Station-Keeping Watch Circle	1- 100 yards (programmable)
Run Time on Station	40 hours
Physical Size L x W x H	60x40x36 inches
Max Overboard Weight	150 lbs



SKB in Rougher Seas

Potential Applications

- **Portable Tracking System**
 - Track Standard MK84 Pinger
 - Splash/Impact Localization
- **Autonomous Monitoring Station**
 - Marine Mammals
 - Harbor Defense
- **Environmental Characterization**
 - Ambient Noise
 - Temperature
 - Conductivity
 - Sound Velocity
 - Turbidity



Exploiting the Environment for Station-Keeping



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WavePlane



OPT PowerBuoy™



**Rockwell Scientific
Wave Energy Harvester**



Solar Powered UUV



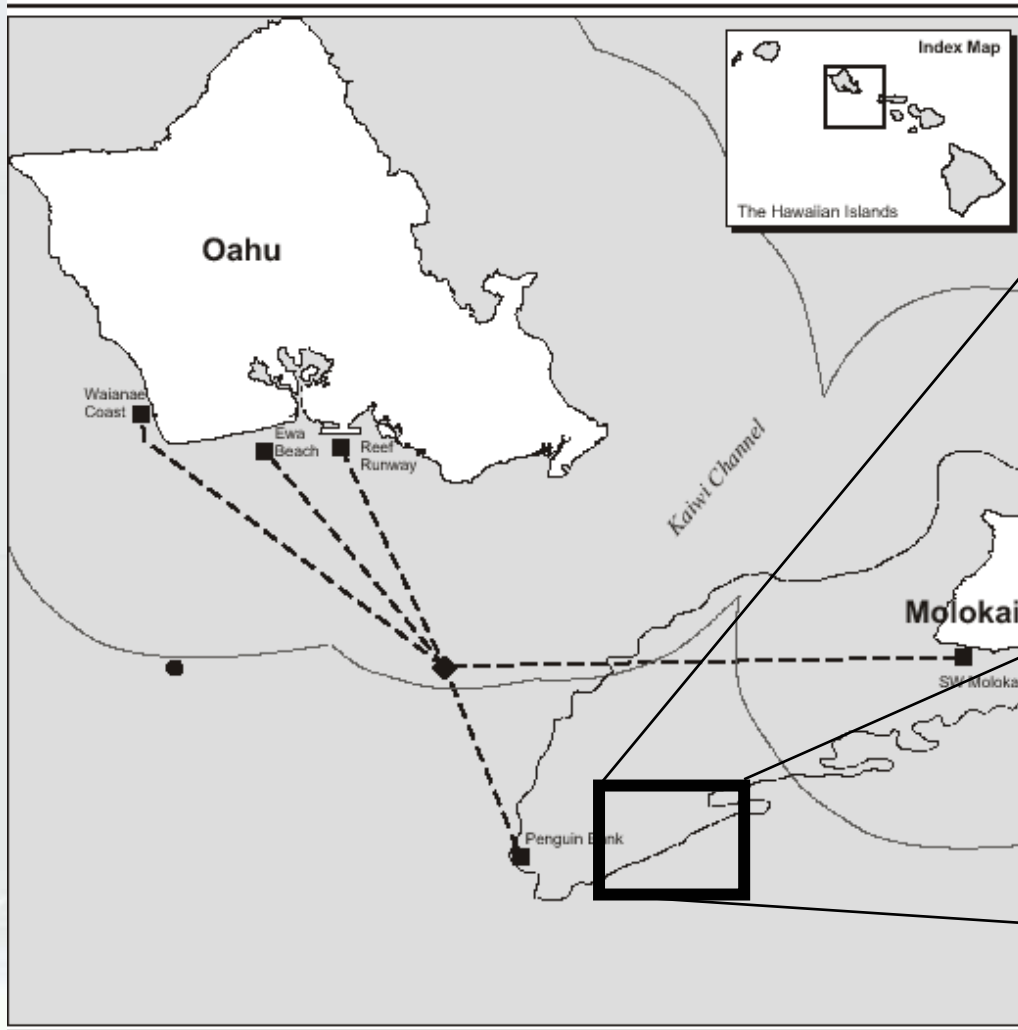
Wind and Ocean Swell Power



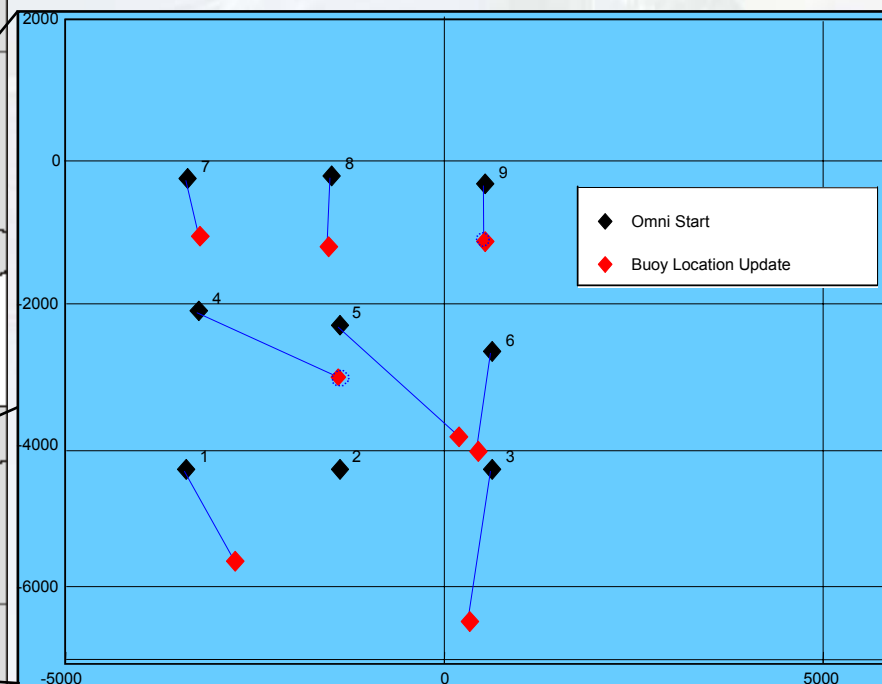
Pelamis Wave Energy Converter



Underwater Glider



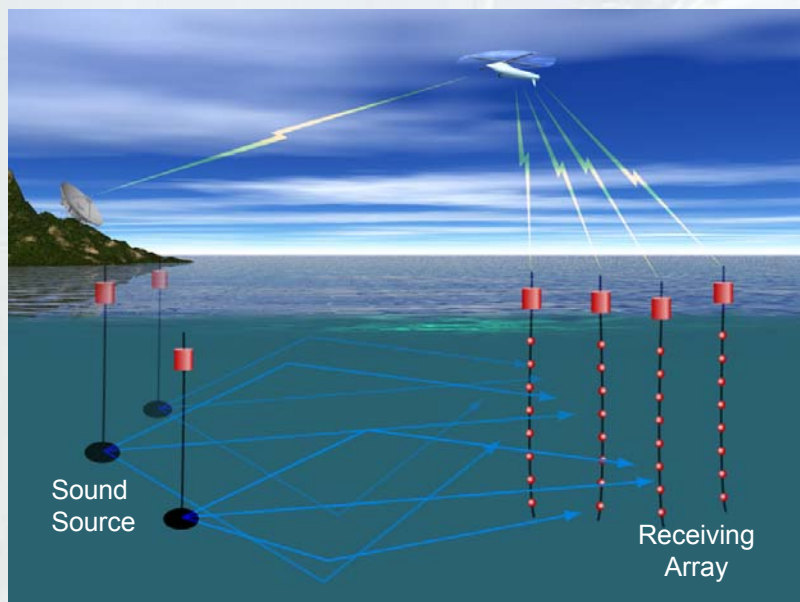
- Direction and rate varies over small area
- Pattern integrity suffers



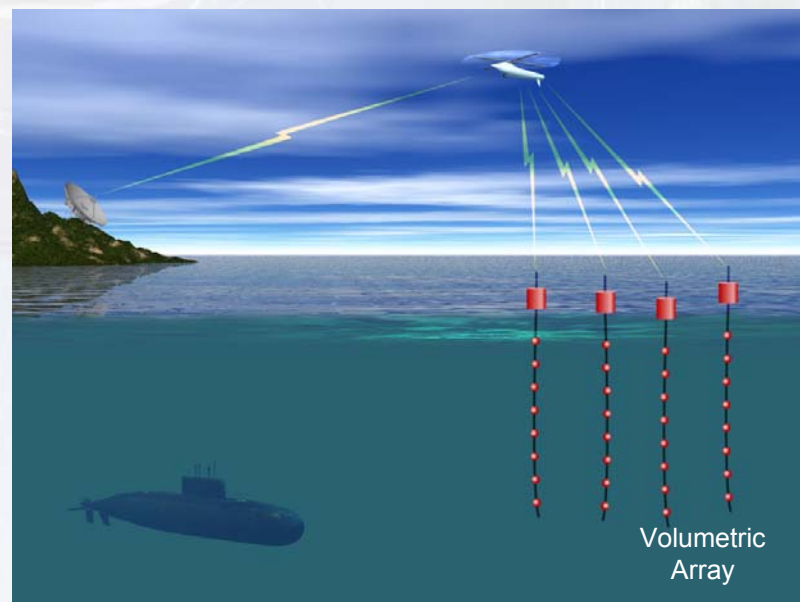
- *Station keeping at 250 meters is approximately the size of the black diamond*

- Task Force ASW - Persistent Ocean Surveillance
- Tactical Oceanography
- Potential for new underwater array concepts

New concepts for underwater arrays



- Station-Keeping Tomographic Imaging System for 3-D sound velocity profiles
- Improved ASW performance predictions based on time-varying and range dependent conditions



- Improved ASW performance using variable aperture volumetric arrays matched to threat and environmental conditions
- Persistent ASW sensor fields



Program Plan



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- **Phased Approach**

- **Phase 1**

- **Detail station keeping design and build prototype**
 - **Develop high fidelity simulation**
 - **Design energy harvesting system**
 - **Demo station-keeping prototype for 1 day**

- **Phase 2**

- **- Complete buoy design including energy harvesting**
 - **- Refine station-keeping control**
 - **- Demo buoy with energy harvesting system for 7 days**

- **Phase 3**

- **Refine energy harvesting/station keeping & build final prototype**
 - **Demo station-keeping for 30 days**

- **Phase 1 and Phase 2 Funding *Estimate***

- **\$2-3M per award over 24 months**
 - **Offeror cost should be based on technology proposed and labor required**



Phase I



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- Investigate issues for tactical-sized station-keeping buoys
 - Develop high-fidelity, physics based simulation to predict buoy performance
 - Use Navy/NOAA data for sea currents, winds, wave-heights, swell, and water temperature data (multiple locations)
 - Determine station-keeping performance as a function of key design parameters (hull type, size, drag, etc.).
 - Quantify degraded hydrophone performance estimates due to motion induced noise in terms of figures of merit such as detection range
 - Modeling and simulation results should demonstrate with high confidence an endurance of one month with a station keeping tolerance of less than 250 meter average error over a 24 hour time period
 - Maximum sea state is Beaufort Scale 5: wind speed 17-21 knots; moderate waves; wave height 7 feet.
 - The Navy/NOAA data defines the duration and periodicity of the sea states over the one month time period
- Develop energy harvesting concepts
- Demonstrate of the station- keeping technology maintaining a 250 meter watch radius over a 24 hour period (Energy harvesting technologies are not required to be demonstrated in this phase)



Phase II



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- Refine the station keeping technologies
- Update modeling and simulation to reflect lessons learned
- Modeling and simulation results demonstrating an endurance of one month with a station keeping tolerance of less than 250 meter average error over a 24 hour time period
 - Maximum sea state is Beaufort Scale 6: wind speed 22-27 knots; rough large waves; wave height 10 feet).
 - The Navy/NOAA data defines the duration and periodicity of the sea states over the one month time period
- Incorporate energy harvesting technologies
- Demonstrate energy harvesting technology while maintaining less than a 250 meter watch radius 90% of the time for one week



Phase III



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- **Refine the energy harvesting and station keeping techniques**
- **Fabricate a long-term station keeping prototype buoy system**
- **Demonstrate a prototype station-keeping buoy maintaining a 250 meter watch radius for 90% of the time and 2,500 meter watch radius 100% of the time over a four week period.**
 - **Geo-location technology (e.g., GPS)**
 - **Station keeping technology (e.g., wind, propeller, thrusters, thermal, currents, buoyancy, gravity, etc.)**
 - **Control system**
 - **Communication system (e.g., Iridium)**
 - **Undersea warfare sensor (acoustic hydrophone)**
 - **Energy harvesting/power system (e.g., wind, wave, solar, currents, buoyancy, etc.)**



Tactical-Sized Buoy Requirements



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Phase	Go/No Go Criteria
Phase I	<ul style="list-style-type: none">• Station keep < 250 m watch radius for 1 day (Beaufort Scale 5)• Simulation/modeling results demonstrating station keeping < 250 m over four weeks.
Phase II	<ul style="list-style-type: none">• Sustained power for 1 week• Station keeping < 250 m watch radius 90% of the time for 1 week (Beaufort Scale 6)



Do's and Don't



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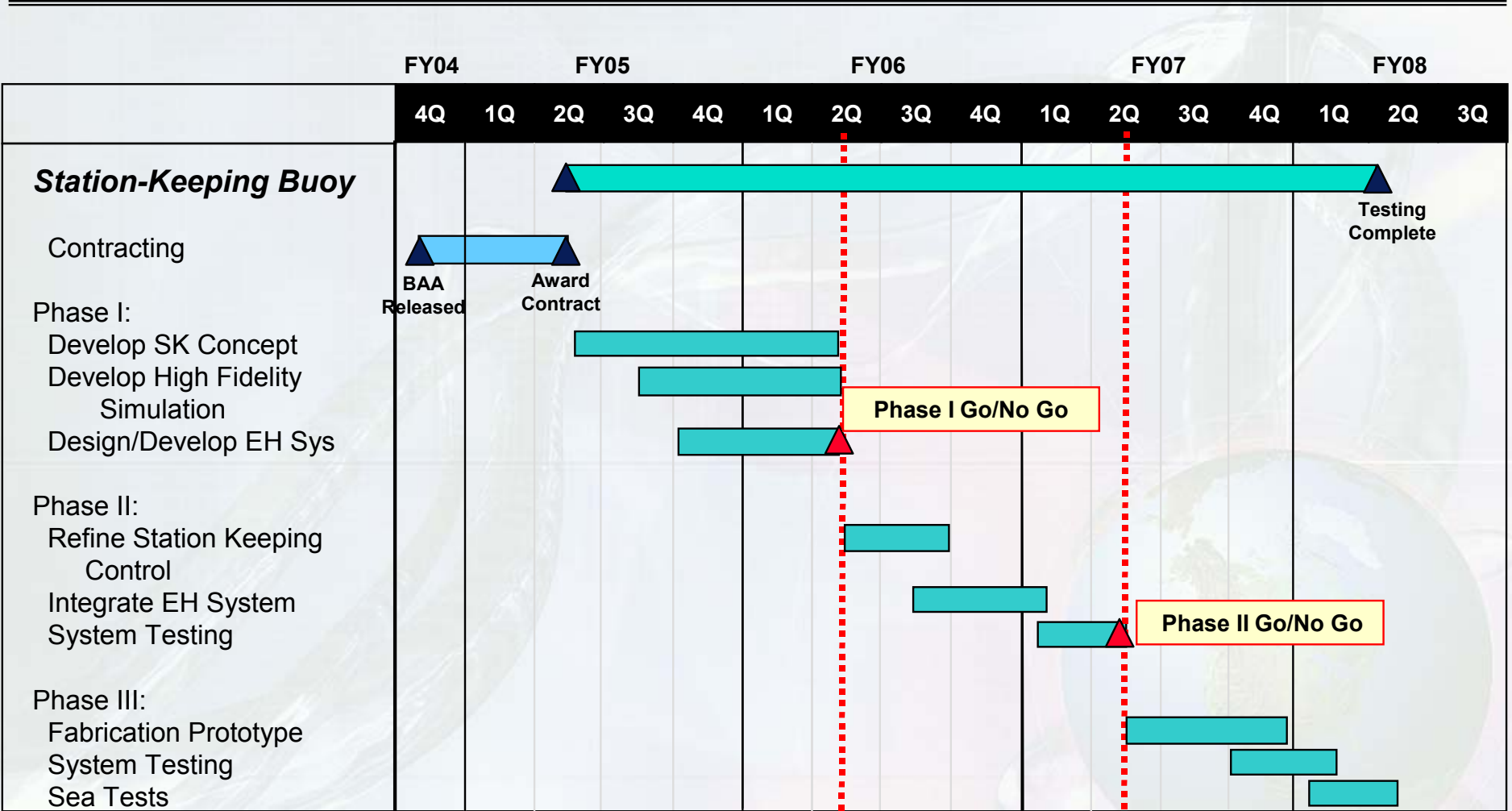
- **Do submit concepts that provide an entirely new military capability or enhance existing capability by orders of magnitude**
 - Address how your concept provides military utility (what's the impact?)
 - Address what's new or what's changed
 - Be concise in describing what you are trying to do
 - Explain the fundamentals of how your concept works
 - Clearly describe what will DoD will have in hand at the end of the effort
- **Don't submit concepts that are extensions to existing systems or minor improvements**
- **Do address in the context of your concept what technical trades will be performed**
- **Don't be "concept content free" and all "process"**
 - Not looking for a series of trade studies that end up with a concept
 - Looking for a concept that will be detailed via specific trade studies



Notional Schedule



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- **Technical Agent**
 - PMA-264
- **Transition Customers**
 - Oceanographer of the Navy
 - PEO Integrated Warfare Systems
 - PMA-264 (Air ASW)



Back-up



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NOAA/Navy Databases



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- Wave Height/Currents/Winds/Swell/Air Temperature:
National Data Buoy Center [\[NDBC\]](http://www.ndbc.noaa.gov/),
<http://www.ndbc.noaa.gov/>
- Fleet Numerical
<https://www.fnmoc.navy.mil/PUBLIC/>
- Naval Oceanographic Office
<http://pdas.navo.navy.mil/>

B Size Buoy

A Size Buoy





Sonobuoy Sizes



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Size	Diameter	Length	Max Weight
A-Size	123.82 +0, -3.18 mm 4.875 +0, -0.125 in	914.40 +3.18, - 4.78 mm 36.00 +0.125, - 0.188 in	17.69 Kg 39.00 lbs
B-Size	174.62 +0, -3.18 mm 6.875 +0, -0.125 in	1524.00 +0, - 6.35 mm 60.00 +0, -0.25 in	
C Size	247.65 +0, -6.35 mm 9.75 +0, -0.25 in	1524.00 +0, -6.35 mm 60.00 +0, -0.25 in	
D Size	76.20 +0.76, -0.76 mm 3.0 +0.03, -0.03 in	381.00 +0, -2.29 mm 15.00 +0, -0.09 in	
F Size	123.82 +0, -3.18 mm 4.875 +0, -0.125 in	304.80 +0, -4.75 mm 12.00 +0, -0.187 in	5.44 kg 12.00 lbs.
G Size	123.82 +0, -3.18 mm 4.875 +0, -0.125 in	419.00 +0, -4.75 mm 16.50 +0, -0.187 in	8.16 kg 18.00 lbs



Beaufort Scale



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Beaufort Number	Description	Mean Wind Speed (Knots)	Deep Keel Criteria	Sea State, Description, Wave Height (Open Sea - ft)
0	Calm	<1	Boom swings idly in swell	Calm - mirror smooth 0 ft
1	Light Air	1-3	Sails just fill, telltales unreliable	Calm - scaly ripples 0.3 ft
2	Light Breeze	4-6	Controlled way, wind gauges reliable	Smooth - small wavelets with glassy crests 0.6 ft
3	Gentle Breeze	7-10	Good way, light flags fully extended	Smooth - large wavelets, crests may break but are glassy 2 ft
4	Moderate Breeze	11-16	Best working wind, genoas at optimum	Slight - small waves, fairly frequent, many white horses 3 ft
5	Fresh Breeze	17-20	Genoas near limit, yachts near hull speed	Moderate - moderate waves, many white horses 7 ft
6	Strong Breeze	22-27	Cruising craft seek shelter, sails reefed	Rough - large waves, foam crests, spray may blow off 10 ft
7	Near (moderate) Gale	28-33	Racing yachts only, spinnakers just	Very Rough - heaped sea, white foam in streaks 13 ft
8	Gale (fresh gale)	34-40	Only of necessity, storm canvas or heave-to	High - moderate high waves, crests break to spindrift 18 ft
9	Severe (strong) Gale	41-47	Craft seek deep water, run warps etc.	Very High - high waves, dense foam streaks, tumbling crests 23 ft



Beaufort Scale



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Beaufort Number	Description	Mean Wind Speed (Knots)	Deep Keel Criteria	Sea State, Description, Wave Height (Open Sea - ft)
10	Storm (whole gale)	48-55	Almost the ultimate, deep water sea room	Very high - very high waves, overhanging crests, sea takes on a white appearance 30ft
11	Violent Storm	56-63		Phenomenal - exceptionally high waves, crest blown to froth, visibility affected 38ft
12	Hurricane	>64		Phenomenal - the air is filled with foam and spray, sea completely white, visibility seriously affected 47 ft
13-17	Hurricane or Local Name	up to 100		